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PRELIMINARY INVESTIGATIONS OF STORAGE BATTERY LOCOMOTIVES

SPECIFICATIONS
LABORATORY TESTS
PERMISSIBLE SCHEDULE

BY

L. C. ILSLEY and H. B. BRUNOT

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PRELIMINARY INVESTIGATION OF STORAGE-BATTERY LOCOMOTIVES; SPECIFICATIONS, LABORATORY TESTS, PERMISSIBLE SCHEDULE.

By L. C. Ilsley and H. B. Brunot.

INTRODUCTION.

The rapid introduction during the last decade of storage-battery locomotives in coal mines has been followed with much interest by the Bureau of Mines for two reasons that relate to safety. Use of these locomotives tends to do away with trolley wires except on main haulage roads, and therefore the danger of electric shock from bare trolley wires is lessened, and trolley lines need not be extended into gaseous sections of a mine. Storage-battery locomotives, however, are a possible menace to safety. They were not designed for use in the gaseous section of mines, and their use in such places had been gradually increasing because the danger was not generally recognized.

In order to bring this problem to the attention of the manufacturers of such equipment, the Bureau of Mines called a conference, May 15, 1916, of manufacturers of locomotives and of batteries for locomotives and representatives of the mechanical and mining divisions of the bureau.

The development of safe, practical equipment for use in gaseous mines was thoroughly discussed. As the cost and therefore the commercial success of such equipment would depend largely upon the extent and character of the safety requirements, the conferees decided that the bureau should prepare a tentative specification covering the minimum safety requirements essential for storage-battery locomotives and submit it to the various manufacturers for criticism. Accordingly, the bureau prepared a set of tentative specifications, termed Specifications of the United States Bureau of Mines for Approved Explosion-Proof Storage-Battery Locomotives, which was submitted to manufacturers, operators, and engineers. Valuable criticisms were received, and the additional information gained was incorporated in a second draft, termed Specifications of the United States Bureau of Mines for Permissible Storage-Battery Locomotives. This draft was submitted to the manufacturers. After some slight changes the latter draft was accepted by all interested parties, but then, owing to the demands of war work, the matter was set aside.

Early in 1919 the bureau took up this matter again and inquired of the different manufacturers whether locomotives that would be safe for use in gaseous mines were commercially feasible, and if so whether they intended to build such locomotives and whether they still wished to cooperate with the bureau in the development of safe equipment for this class of service.

The manufacturers manifested willingness to cooperate further and suggested, as considerable time had intervened and commercial conditions had changed, that another conference be held and the whole subject be carefully reconsidered. This conference was held at the Pittsburgh experiment station of the bureau July 29, 1919.

Preceding the conference, the bureau incorporated the second draft of specifications in the standard form of a permissible schedule in order that the conferees might discuss the proposed schedule and decide whether or not the bureau should attempt to establish a permissible list of storage-battery locomotives along the same general lines that had been followed in approving certain other equipment for use in gaseous mines.

Several minor changes and additions suggested by the manufacturers were made to the schedule, after which it was published under date of August, 1919, as Schedule 15.

While preparing the tentative specifications the bureau conducted preliminary investigations of storage-battery locomotive accessories to disclose hazards that were believed to affect the safety of storage-battery locomotives when used in mines where there might be accumulations of fire damp.

This paper tells of the development of the specifications that led to the preparation of Schedule 15 and gives data obtained in the preliminary investigation in order to assist those who are developing apparatus to meet the requirements of Schedule 15.

ACKNOWLEDGMENTS.

Acknowledgment for the valuable criticisms and suggestions given or for assistance rendered by supplying material for use in laboratory investigations is made to the Edison Storage Battery Co., the Electric Storage Battery Co., the Philadelphia Storage Battery Co., the Gould Storage Battery Co., and The Mine Safety Appliances Co.

Acknowledgment is also made for constructive criticism to the following manufacturers of storage-battery locomotives: The Lakewood Engineering Co., the Jeffrey Manufacturing Co., the General Electric Co., the Westinghouse Electric & Manufacturing Co., the Geo. D. Whitcomb Co., the Ironton Engine Co., the Goodman Manufacturing Co., the Atlas Car & Manufacturing Co., and the Mancha Storage Battery Co.

Credit is due to George W. Schleuderberg and A. B. Kiser, of the Pittsburgh Coal Co.; to D. H. Cobel and A. W. Chandler, of the H. C.

Frick Coke Co.; and to George T. Watson and R. L. Kingsland, of the Consolidated Coal Co., for valuable criticism.

The committee on electricity in mining (advisory to the Bureau of Mines) of the American Institute of Mining Engineers, William Kelley, chairman; C. M. Means, consulting electrical engineer of the bureau, and the mining division of the bureau, represented by George S. Rice, chief mining engineer, also gave valuable assistance.

O. P. Hood, chief mechanical engineer of the bureau, had general charge of the work and acted as chairman at the conferences. The immediate supervision of the work was under H. H. Clark until the latter part of 1917, and afterward L. C. Ilsley was in charge. The following junior electrical engineers of the bureau assisted in conducting the laboratory tests: R. W. Crocker, O. C. Heffner, O. I. Gaines, E. J. Gleim, A. B. Hooker, N. F. Fleming, and W. V. Wolfe.

FIRST CONFERENCE, MAY 15, 1916.

The first conference was attended by about 20 representatives of the various manufacturers of storage batteries and storage-battery locomotives, who met at the Pittsburgh experiment station of the bureau the representatives of the bureau's mechanical and mining divisions.

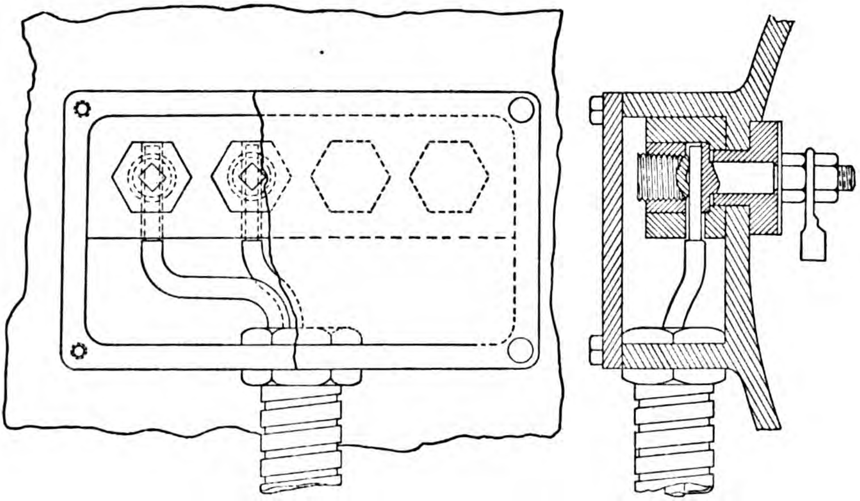

FIGURE 1.—Application of explosion-proof studs to the motor of a storage-battery locomotive.

As a basis for discussion, the bureau's engineers had outlined the various problems that would have to be solved in developing safe battery locomotives, and made several sketches indicating possible solutions for some of these questions in the light of the bureau's experience with similar equipment. The outlines included a list of the special features that require protection in storage-battery locomotives but are not found in coal-cutting equipments, and a summary of

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storage-battery locomotive parts that require protection. Two of the sketches prepared for this conference are given herewith. Figure 1 shows the details of an approved explosion-proof connection stud for leads; figure 2 illustrates various types of protection, devices and flange protection.

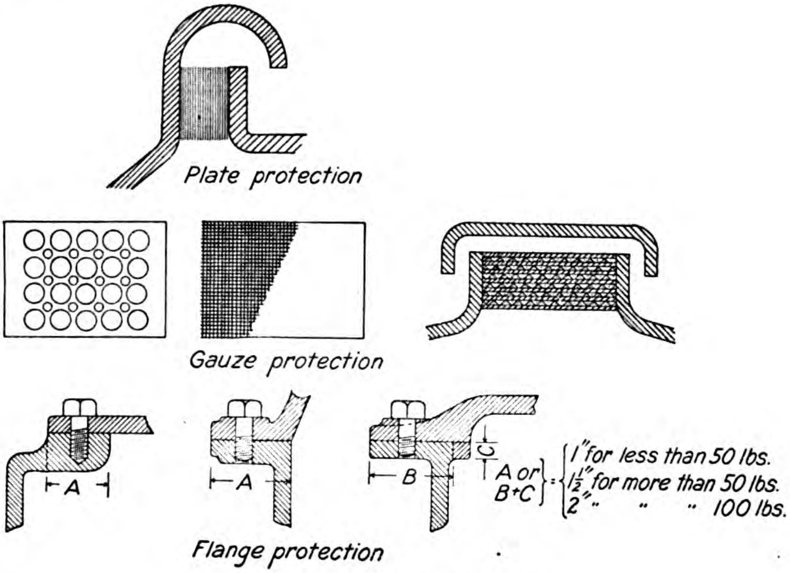

FIGURE 2.—**Types of protection.**

After a discussion of possible dangers, methods of protection, and the commercial feasibility of producing safe equipment, the conferees decided that a minimum specification be prepared by the bureau and submitted to the several manufacturers for criticism. The bureau therefore prepared the first draft of its specifications for "approved explosion-proof storage-battery locomotives."

LABORATORY AND FIELD INVESTIGATIONS.

The first draft of the specifications was tentative as many of the points had been decided from theory only. Specific information was therefore desirable and necessary, both as a check upon the effectiveness and practicability of the specifications and to supply data that would aid in the safe and practical solution of the various problems involved. Hence, the bureau undertook laboratory and field investigations, as follows:

1. Investigation of possible danger from storage-battery locomotive headlights.
2. Investigation of the possible danger from abrasive sparks.

3. Investigation of locomotive battery equipment.
    (*a*) Liability of arcs from broken or loose connections.
    (*b*) Liability of internal explosion of cells.
    (*c*) Liability of dangerous current leakage over surface of cells and trays.
4. Application of the information obtained in previous investigations of permissible equipment.
5. Investigation of conditions found in actual operation by—
    (*a*) Questionnaire sent to operators.
    (*b*) Personal inspection by bureau engineers.

POSSIBLE DANGER FROM STORAGE-BATTERY LOCOMOTIVE HEADLIGHTS.

The bureau had already investigated the danger of explosion from incandescent lamps, and published the results in Bulletin 52.[1] This danger arises from the liability of explosive gas mixtures being ignited when allowed to come in contact with a glowing filament through bulb breakage, as the temperature of the filament of an incandescent lamp is above the ignition temperature of gas. The possibility of the sparks from breaking a circuit causing an explosion of a surrounding explosive gas mixture had also been investigated and published in Technical Paper 47.[2] That the dangerous condition might arise from the use of poorly designed or improperly installed headlight equipment was known. In order to obtain information that would aid in solving the problem, three sets of tests were made, as follows: Smash tests on various types of headlight lamps; sparking tests, between contacts in gas mixtures; and a test of an experimental safety headlight equipment.

SMASH TESTS OF VARIOUS TYPES OF HEADLIGHT LAMPS.

Smash tests consisted in smashing lighted lamps while surrounded by the most explosive mixture of Pittsburgh natural gas and air (8.6 per cent gas) under the conditions described below.

Gallery No. 3 (Pl. I, *A*, p. 12) was used to prepare and contain the gas mixtures. This gallery is a gas-tight steel box fitted with a steel-framed glass door *a*, and observation windows *b;* pressure relief in case of violent explosion is provided by the opening *c*, which is normally closed with paraffined paper. The proper amount of gas was measured by the sensitive meter *d* and passed into the gallery through the mixing fan *e*. A steel rod sliding in the bushing *f* was used to smash the lamps, which were held by pressure applied to their tips in such a manner that breakage released the lamps from contact and opened the lamp circuit.

---

[1] Clark, H. H., and Ilsley, L. C., Ignition of mine gases by the filaments of incandescent lamps: Bull. 52, Bureau of Mines, 1913. 31 pp.

[2] Clark, H. H., Portable electric mine lamps: Tech. Paper 47, Bureau of Mines, 1913. 8 pp.

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Table 1 gives the sizes, types, and number of lamps tested and the results obtained:

TABLE 1.—*Number, rating, and types of lamps smashed and results obtained.*

Type of lamp.	Rating of lamps.		Number tested.	Number of tests in which ignition occurred.	Number of tests in which ignition did not occur.
	Volts.	Watts.			
Distributed filament, vacuum type	125	25	1	....	1
Do	125	40	23	3	20
Do	125	60	23	10	13
Concentrated filament, vacuum type	125	40	3	3	....
Do	125	60	3	3	....
Concentrated filament, nitrogen filled	125	75	3	3	....

In all tests the bulbs were completely demolished. The filaments were destroyed in some tests and in others were more or less damaged.

Out of a total of 56 successful trials ignition took place in 22 or in 39.3 per cent of the tests. In the trials with the concentrated filament type ignition occurred in all of the tests, whereas with the distributed filament lamps ignition was obtained in only 27.7 per cent. The presence of the inert gas, nitrogen, in the concentrated filament lamps did not prevent ignition.

The smash tests proved that 125-volt metal-filament lamps offer a real hazard if they are used on mining locomotives that may enter gaseous atmospheres and that either the headlights should be protected, so as to prevent breakage of the bulbs, or some means should be used that will interrupt the circuit before the bulb can be broken.

SPARKING TESTS BETWEEN CONTACTS IN GAS MIXTURES.

In order to simulate conditions that might occur in opening a commercial headlight circuit, the current in a 125-volt circuit was interrupted between roughened brass and copper contacts at a speed of 0.39 inch per second while the contacts were surrounded by the most explosive mixture of Pittsburgh natural gas and air. For this test a contact-breaking device with a stationary contact one-sixteenth inch wide was operated in gallery No. 3. (See Pl. I, *A*.)

Four hundred and forty interruptions were made with a current of 0.55 amperes before ignition took place. Then the current was reduced to 0.50 amperes and 5,000 trials made without causing ignition. The current was raised to 0.55 amperes again and an explosion obtained after 44 trials. At intervals throughout the test the contacts were roughened by breaking a current of 2 amperes during several revolutions of the contact disk.

The test shows that the sparks resulting from opening 125-volt circuits carrying currents as low as 0.55 amperes can ignite gas. Also the tests emphasize the need of careful wiring in the headlight circuit and of not changing lamps or doing work on a headlight or headlight circuits when the locomotive is in a gaseous section of a mine.

TESTS OF AN EXPERIMENTAL HEADLIGHT EQUIPMENT.

The experimental safety headlight used in this investigation was supplied the bureau by the Mine Safety Appliances Co. from drawings furnished it by the bureau's engineer.

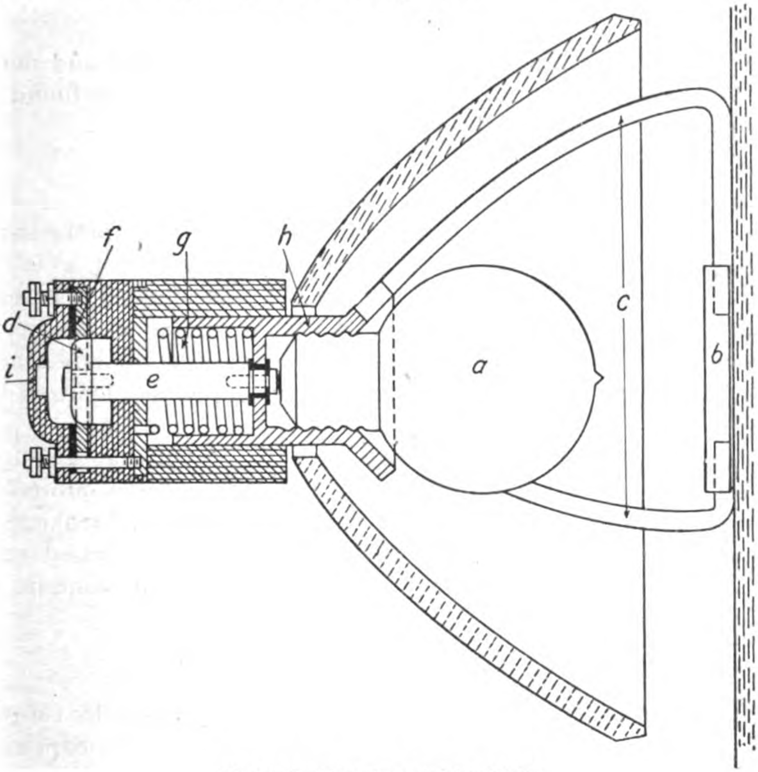


FIGURE 3.—**Experimental headlight.**

A diagram of the headlight is shown in figure 3. The lamp *a* is protected from mechanical injury by a brass disk, *b*, which is supported by the three brass fingers, *c*. A rectangular contact, *d*, on the end of rod *e* is held in a slot in the metal disk *f* against the pull of spring *g* by the twisting force of this same spring. If the contact *d* becomes dislodged from the slot in *f*, as the result of a blow, the spring *g* should draw the contact with the rod *e*, the lamp socket *h* and the disk *b* toward the end cover *i* of the apparatus and thus open the lamp circuit.

In testing the apparatus no attempt was made to ignite gas. The headlight was supported by a rack in the proper relative position to a standard headlight door and observation was taken of the action of the two safety features, the circuit-opening device, and the mechanical protecting disk, under blows delivered against the door glass. Ten trials were made. The results were as follows:

Results of tests of experimental headlight.

Number of tests	10
Number of tests in which circuit-opening device worked	4
Number of tests in which lamp bulb was broken	1
Number of tests in which door glass was broken	9

The results show that the device was too complicated and unreliable to be of practical use, and that a solution might be found in better protection of the bulb from mechanical injury.

SUMMARY OF TESTS OF HEADLIGHTS.

Although the scope of the headlight tests was not comprehensive, the danger of explosion from broken bulbs is clearly shown, as is the probability of the failure of safety devices that depend for their operation on lamp breakage. Moreover, such safety devices probably would not be kept in good repair and would thereby add a new danger unless protection were provided against possible ignition by sparks.

The information gained from these tests indicates that a simple headlight of substantial construction, with a heavy, well-protected door glass so installed and guarded that the danger of breakage is minimized, may be the safest. There should be no exposed contacts in a headlight and all wiring to it should be in conduit or flexible armor.

DANGER FROM ABRASIVE SPARKS.

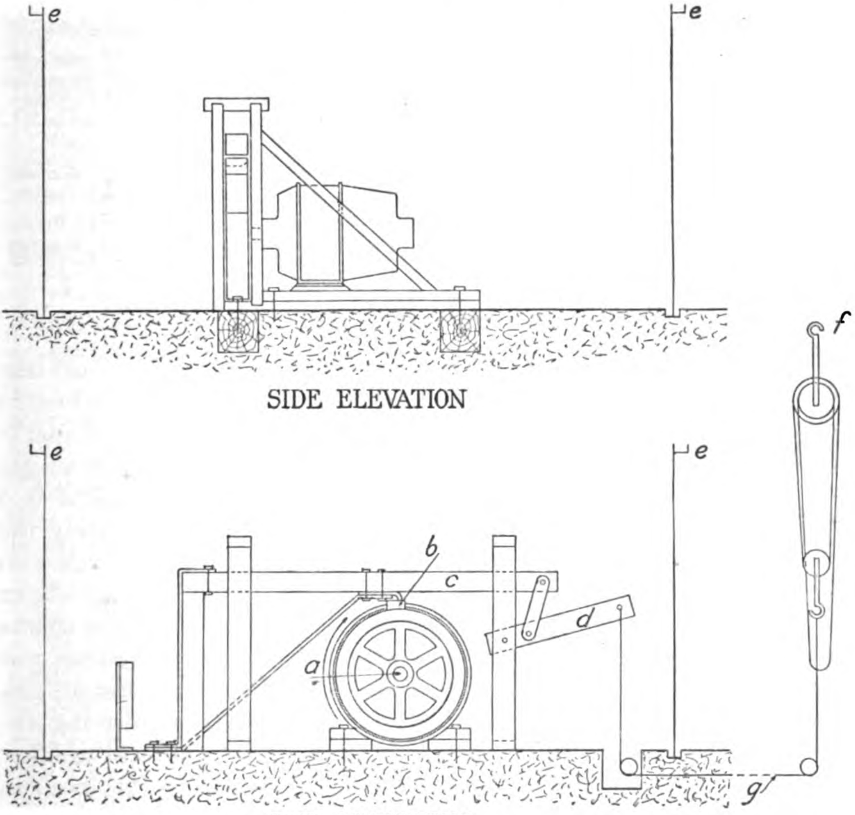
Tests were made to determine whether or not the sparks thrown off by mine-locomotive brakes and wheels would ignite explosive gas mixtures.

CHARACTER OF TESTS.

The first tests were made with a standard mine-locomotive driving wheel and experimental brake shoes; but with the small amount of power available, neither ignition of an 8.6 per cent gas mixture nor satisfactorily severe sparking could be obtained. Consequently, in the later tests, a carborundum grinding wheel and various cast-iron and steel samples were used to produce the sparks.

EQUIPMENT, MATERIALS, AND APPARATUS.

A 7½-horsepower, 250-volt, 850-revolutions-per-minute, direct-current motor was arranged to drive the 24-inch locomotive and the 13-inch carborundum wheels. Figure 4 shows the general "set up" of the tests in gallery No. 5. The wheel *a* was mounted directly on the motor shaft and pressure was applied to the brake shoe *b* by means of the levers *c* and *d*, which were operated from outside the gallery walls *e* by the chain hoist *f* through the rope *g*. With this arrangement it was possible to manipulate the apparatus from the outside when the gallery was filled with explosive gas.



SIDE ELEVATION

END ELEVATION

FIGURE 4.—General "set-up" of apparatus for abrasive-spark test.

A list of the materials used and data on the various brake shoes and steel specimens follows:

List of materials used to produce sparks.

One 24-inch standard chilled cast-iron mine-locomotive drive wheel.
One 13-inch medium carborundum grinding wheel.
Several experimental brake shoes, of cast iron and aloxite, of different shapes and sizes.
Four steel specimens.

TABLE 2.—*Dimensions and material of brake shoes used in abrasive spark test.*

Shoe No.	Dimensions of bearing face of shoe.			Material.	Shoe No.	Dimensions of bearing face of shoe.			Material.
	Length.	Breadth.	Area.			Length.	Breadth.	Area.	
	Inches.	*Inches.*	*Sq. inches.*			*Inches.*	*Inches.*	*Sq. inches.*	
1	4	2⅝	10.50	Cast iron.	4	1½	1½	2.25	Cast iron.
2	3	1¼	3.75	Do.	5	8	1⅜	11.00	Aloxite.
3	1¼	2¼	2.82	Do.					

TABLE 3.—*Data concerning steel specimens used in abrasive spark test.*

Specimen No.	Dimensions.	Class of steel.	
		Carbon content.	Heat treatment.
		Per cent.	
1	1 by 1 by 3 inches	1.25	Hardened.
2	1⅛ by 1⅛ by 3 inches	1.00	Do.
3	1⅜ by 1⅜ by 3 inches	1.40	Do.
4	1 by 1 by 3 inches	1.25	Annealed.

TEST OF CAST IRON AND ALOXITE SHOES.

The first series of tests was made in air with the chilled cast-iron wheel and cast-iron shoes, face area 2.25 to 105 square inches, in order to obtain a general idea of the character and quantity of sparks obtainable with these materials. One test was then made in gas without causing an explosion. In this test a shoe having a face area of 2.66 square inches was used, as it gave approximately the same pressure per square inch as would be required for the brakes on 30-ton locomotives operated at 15 miles per hour. Some tests in air were also made with a sample "aloxite" shoe. Very few sparks were produced in any of the tests and with none of the shoes was the sparking severe enough to warrant the tests being tried in gas.

Owing to the small capacity of the motor used in driving the chilled cast-iron wheel in the previous tests, it was doubtful whether enough energy had been dissipated by the experimental shoes to simulate closely the actual operating conditions. Therefore to determine, if possible, the amount of sparking necessary to cause ignition of gas various specimens of steel and cast iron were tried with the carborundum grinding wheel. As a result of preliminary tests high-carbon steel was selected as likely to give the largest number of hottest sparks.

The most intense sparking conditions obtainable with the equipment were then produced in explosive gas mixtures (8.6 per cent gas) without causing ignition. Large quantities of sparks were obtained from all the steel specimens, and the two smaller ones became red-hot over the surface next to the grinding wheel. The cast-iron shoe applied to the carborundum wheel produced a good shower of reddish sparks.

Microscopic examination of the particles produced by grinding was made. Table 4 briefly summarizes the test conditions and results.

TABLE 4.—*Summary of conditions and results of abrasive spark test.*[a]

Source of sparks.		Character and quantity of sparks (maximum condition.)	Heating of shoe or specimen.	Surrounding atmosphere.	Microscopic examination of particles.	Remarks.
Abrador or shoe.	Wheel.					
Cast iron..	Chilled cast iron.	Few; occurring in spurts.	Smaller shoes red-hot on face.	Air (0.0 per cent gas).	None made.....	4 shoes, face areas ranging from 10.5 square inches to 2.25 square inches.
Do.....	...do......	Few; occurring in spurts mostly at start.	Red-hot on face.	Gas mixture (8.6 per cent).	.....do..........	Shoe No. 3. Horse-power absorbed per square inch of shoe face=2.6.
Aloxite....	...do......	Few sparks.....	....	Air (0.0 per cent gas).	.....do..........	Area of face of shoe abraded, 3.45 square inches.
Cast iron..	Carborundum.	Dull red sparks in large amounts	Cherry red on face.	Both (8.6 per cent) gas and air (0.0 per cent gas).	No evidence of melted metal.	Area of face of shoe 3.75 square inches. Shoe No. 2 used in test.
Steel......	...do.......	Large number of sparks.	Red-hot in some tests.	Gas mixture (8.6 per cent gas).	Small globules of melted steel, abraded particles of steel and wheel found.	5 trials in all, 2 with specimen No. 3 and 1 with each of the others.

[a] No ignitions during these tests.

These tests demonstrated that an ignition of gas by sparks caused by abrasion of brake shoes on locomotive wheels is not liable to take place. Further tests, with different materials or with more absorption of energy, might give different results; however, these tests show that the danger is slight.

LOCOMOTIVE BATTERY EQUIPMENT.

Three possible sources of danger were investigated in connection with storage batteries. The liability of arcs from broken or loose connections; the liability of internal explosion of cells; and the liability of dangerous current leakages over surfaces of cells and trays.

LIABILITY OF ARCS FROM BROKEN OR LOOSE CONNECTIONS.

Arcs from broken or loose connections in the battery compartment would be almost certain to cause explosions if the arcing occurred in gaseous places. Therefore to determine the likelihood of breakage as a result of the jarring incident to locomotive service, several sets of tray connectors were tested.

SCOPE OF TESTS ON BATTERY TRAY CONNECTORS.

Two types of connectors were used in the tests. These are designated as types A and B, and the tests for convenience are divided into three sets, as follows: (1) A preliminary set, with type A and type B connectors; (2) a set of trial tests on a special testing machine with type B connectors; and (3) a final set of tests, with both type A and B connectors.

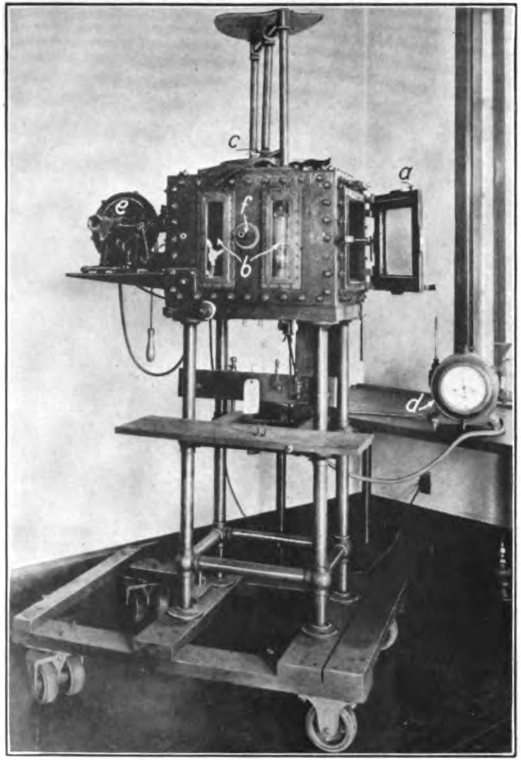
APPARATUS AND EQUIPMENT USED IN TESTS OF BATTERY CONNECTORS.

The first two sets of tests were made for the purpose of developing a standard method for testing the durability of storage-battery tray connectors. The preliminary tests were made with a machine used by the bureau for testing the durability of the cord for miners' electric cap lamps. This test was found to be too severe, and, besides, the motion imparted to the conductors was not the same as that to which they would be subjected in service. A special machine was therefore designed for use in subsequent tests that would more closely represent actual working conditions, and a trial set of tests was conducted with type B connectors. The information gained rendered advisable the modification of the original form of this testing machine. The final set of tests was made with both types A and B and connectors on the standard testing machine finally developed.

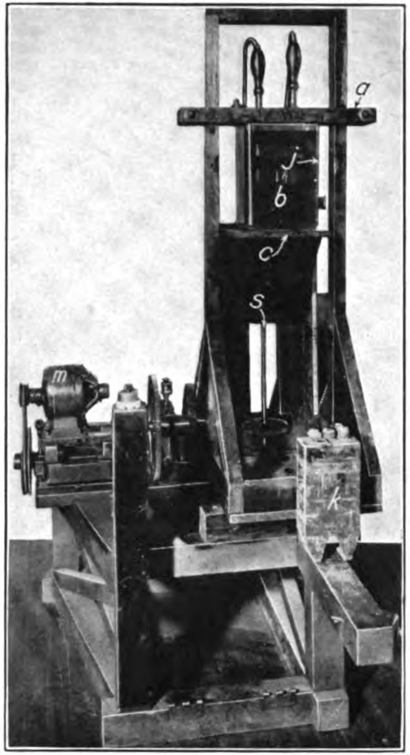
STANDARD MACHINE FOR TESTING THE DURABILITY OF BATTERY TRAY CONNECTORS.

The standard machine developed for testing battery tray connectors is shown in Plate II, *A*. A simple reciprocating motion is given to table *a* by the eccentric *c*, through link *d*, while table *b* is given a rocking motion through links *e*. The ends of the connectors are rigidly fastened to the tables by standard battery-terminal posts. With this arrangement a weaving motion is imparted to the connectors, equivalent to three simultaneous motions of the *a* ends relative to the *b* ends, that is, first, a reciprocating movement of about 0.24 inch (total travel) perpendicular to the length of the conductors; second, a movement of about 0.08 inch in the same plane and at right angles to the first motion; third, a motion of about 0.14 inch perpendicular to both motions one and two.

At the time of the second set of tests, the links *e*, and the spring *s* had not been added and therefore the conditions were less compli-



A. GALLERY NO. 3, USED IN TESTING HEADLIGHT LAMPS.



B. MACHINE USED TO DRAIN ELECTROLYTE FROM BATTERY CELLS.

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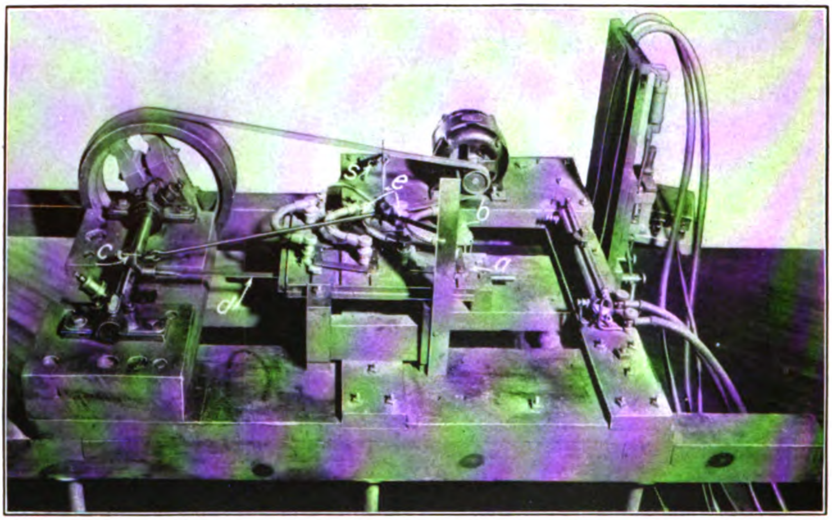
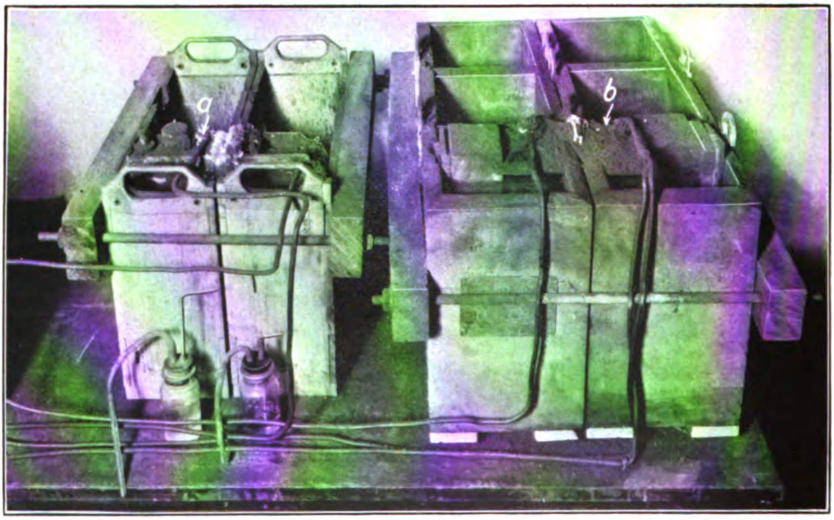


A. STANDARD MACHINE FOR TESTING STORAGE-BATTERY TRAY CONNECTORS.



B. BATTERY SET-UP FOR SURFACE-LEAKAGE TEST.

cated and severe, as table *b* was free to rock back and forth, without constraint, under the pull of the connectors.

The driving-motor method of connecting the jumpers, etc., is shown clearly in the illustration.

MATERIAL TESTED.

The number and specifications of the jumpers used in the different sets of tests were as follows:

Set No. 1, 10 type A connectors. Specifications: 6 inches of No. 00 B. & S. flexible cable between lugs. Cable: 19 strands, 22 No. 25 B. & S. tinned copper wires per strand, with a $\frac{1}{16}$-inch good grade rubber covering over all.

Set No. 2, 4 type B connectors. Specifications: 4 inches of No. 00 B. & S. flexible cable between lugs. Cable: 24 strands, 7 No. 22 B. & S. tinned copper wires per strand, with a $\frac{1}{16}$-inch covering of good grade over all.

Set No. 3, 4 type A and 4 type B connectors with specifications similar to those in sets 1 and 2.

The lugs of the type B connectors are held in place on the tapered terminal posts by hexagon nuts; the lugs of the type A connectors are fastened to the terminals by lead burning.

PRELIMINARY TEST OF TYPE A CONNECTORS.

One end of each of the 10 connectors tested was rigidly clamped to the swing frame of the cap-lamp cord-testing machine; the other end was left free to whip back and forth as this frame made 100 oscillations a minute. At the beginning of the test the free ends bent through an arc of about 2 inches on both sides of their normal positions, but the amount of bending gradually increased as the repeated strains weakened the conductors. After each 50,000 oscillations the connectors were reversed end for end, in order that both ends should receive the same treatment as nearly as practicable.

Table 5 below is a summary of the results obtained in this test.

TABLE 5.—*Results of preliminary test of 10 type A connectors.*

	Number of oscillations to break connectors completely in two.	Per cent resistance increase at 228,500 oscillations (broken connector disregarded).
Maximum	593,900	364
Minimum	228,500	41
Average	392,340	147

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TRIAL TEST—TYPE B CONNECTORS.

To represent more closely the jarring motion of actual service, the special machine described above was built without the links *e* and the spring *s*, and a trial test made with four type B connectors. These connectors were mounted in place on the machine by standard battery terminals, and a current of 60 amperes from a two-volt supply was maintained through them while under test. The results are summarized as follows:

(*a*) The test caused no loosening of the connections.

(*b*) One connector failed after about 1,979,500 oscillations. This connector had a considerable vertical motion which the other three did not have.

(*c*) Three connectors had not failed when the test was discontinued after about 5,158,000 oscillations, but it was found that they had been broken, partly at one end and completely at the other, inside the rubber insulation.

(*d*) The conductors broke at the points where solder had stiffened the wires.

(*e*) The increase in the resistances of the connectors ceased to be regular after about 1,500,000 oscillations.

FINAL TEST OF TYPE A AND TYPE B CONNECTORS.

In the final test the connectors were subjected to a weaving motion in the standard machine, shown in Plate II, *A*, while carrying a current of 60 amperes from a 100-volt supply. The results are summarized in Table 6. Standard battery terminals were used in mounting the connectors on the testing machine. The tests were run for 11,600,000 oscillations with the type A, and 2,171,000 oscillations with the type B connectors. No loosening of the terminal lugs on the terminal posts took place with either type.

CONCLUSIONS.

From a consideration of these tests the danger of loose or broken tray connectors, if properly designed and constructed, does not seem great if adequate inspection of the batteries is maintained. In soldering on the lugs of the type B connectors, if the solder is allowed to run up the wires for half the length of the cable, the flexible cable is stiffened and the life of the connectors is shortened. The type A connectors did not have this defect which fact, together with their longer length, probably accounts for their greater durability on test.

TABLE 6.—*Final tests of battery connectors, types A and B.*

Construction of samples and conditions of test.								Results of test.[a]					
Sample No.	Type of sample.	Average distance between centers of terminal lugs.	Number of strands in cable.	Number of wires per strand.	Size of wires (B. & S. gage).	Average distance between centers of terminal lugs when mounted for test.	Number of oscillations to which samples were subjected.	Failure due to arcing or open circuit.	Place of break and percentage of wires broken.			Condition of insulation.	Increase in resistance of sample.[b]
									Near table *a* end.	Near table *b* end.	In middle section of the cable's length.		
		Inches.				*Inches.*			*Per cent.*	*Per cent.*	*Per cent.*		*Per cent.*
1	Type A	$9\frac{3}{8}$	19	22	25	$5\frac{1}{2}$	[c] 11,600,000	None		1.2		Good	135
2	do	$9\frac{3}{8}$	19	22	25	$5\frac{3}{4}$		do		3.8		do	43
3	do	$9\frac{3}{8}$	19	22	25	$5\frac{3}{4}$		do				do	39.4
4	do	$9\frac{3}{8}$	19	22	25	$5\frac{5}{8}$		do				do	81
5	Type B	6	36	7	24	$5\frac{13}{16}$	2,171,000	do		100	41	Badly split[d]	[e] 50
6	do	6	23	7	23	$5\frac{7}{8}$		do		100	31	Good	[e] 119
7	do	6	23	7	23	$5\frac{7}{8}$		do		100	49	do	[e] 5
8	do	6	23	7	23	$5\frac{13}{16}$		[f] Failure	8	100	4	Broken circumferentially.[g]	[e] 99

[a] After the samples were removed from the testing machine each was examined carefully as to its physical condition.

[b] The rate of resistance increase of samples 1 to 4, inclusive (Type A), was fairly uniform throughout the test, although this rate was not the same for each sample. After about 209,000 oscillations the rates of resistance increase of samples 5 to 8, inclusive, were more or less variable, and it was noted later in the test that the resistances of these connectors were changed several hundred per cent by the variation in the relative positions of their terminal lugs during an oscillation. The average resistance of sample number 8 was less than one-fourth as great after the insulation failed as it had been for some time before.

[c] The test of samples 1 to 4, inclusive (Type A connectors), was halted after about 11,600,000 oscillations as the samples seemed still in good condition and showed no signs of early failure.

[d] The insulation on sample number 5 began to split after about 363,000 oscillations. This failure first developed near one lug but at the end of the test the insulation was gaping open for about three-fourths of the length of the cable. A twist had to be given this sample to bring the terminal lugs into alignment when mounting it on the testing machine.

[e] The per cent increase in resistance for samples numbers 5 to 8, inclusive, is that caused by 209,330 oscillations (see preceding footnote).

[f] The ends of the broken cable of sample number 8 were accidentally separated in examining the break in the insulation, or it might have continued to carry current for some time longer (see footnote [b]).

[g] The insulation on sample 8 split circumferentially around the cable at the point of failure shortly before failure occurred (see preceding footnote).

General "make up" of samples: The connectors consisted of a length of flexible stranded cable between two terminal lugs. The cable was composed of tinned copper wires and covered with about one-sixteenth inch of good rubber insulation.

LIABILITY OF INTERNAL EXPLOSION OF CELLS.

All commercial storage batteries evolve more or less hydrogen, and the presence of this highly explosive gas would be a grave source of danger if it were liable to ignite.

CHARACTER OF TESTS.

The probability of arcs or other conditions sufficient to ignite gas inside the cells does not seem to be great with the electrolyte at its normal level. For this reason tests were made only on cells in which the normal level of the electrolyte had been lowered, representative of conditions that might result from carelessness or accident.

In the evaporation tests two cells were tested. In the leakage tests one cell was tested in group A tests, seven in group B, and four in group C.

EVAPORATION TESTS.

The electrolyte was evaporated by repeatedly charging the cells at their normal charging rates. No water was added during the tests, and in order to hasten the action the cells were not discharged, but were left on open circuit between charging periods. The results of the test are shown in Table 7.

TABLE 7.—*Summary of conditions and results of evaporation test.*

Number of cells tested.	Number of hours charged.	Explosion.	Arcing between plates.	Short circuits between plates.[a]	Heating of cells.	Remarks.
1	170	None.....	Doubtful......	None........	Yes; at positive terminal point of short circuit.	Cell was not completely dried out. Some of insulation was melted at point of short circuit.
1	304	None.....	No evidence of arcing.	After 160 hours.	Highest temperature by thermometer was 85° C.	Gas in cell before the short circuit was explosive, after short circuit it was nonexplosive. Some of cell insulation was burned.

[a] In neither of the cells was there direct metallic contact between the plates, although internal short circuit occurred.

LEAKAGE TESTS.

METHODS.

Leakage tests have been more or less arbitrarily divided into three groups designated A, B, and C, according to the time at which they were actually performed. The tests under group A were preliminary.

In all three groups tests were made under both charging and discharging conditions, with the electrolyte draining from the cells at various rates. Before a test began the cells were reinforced to with-

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stand any internal explosions that might occur, and the containers were cut away, or drilled, at their bottoms to allow the electrolyte to drain out. The bottom of the cell shown at *k*, Pl. I, *B* (p. 12), had been cut away for this purpose. The cells were then placed in a glass jar full of electrolyte and fully charged so that they would be gassing freely, except in the two charging tests of group B, in which the tests were started with the cells on charge.

Two methods were used to lower the electrolyte. During the first part of the investigation the electrolyte was drawn from the jars by means of siphons fitted with nozzles of various sizes. This method proved rather inconvenient, and therefore the machine shown in Plate I, *B* was designed. The cell *b* under test is fastened to the support *a*, and the glass jar *j* full of electrolyte rests on the platform *c*, which is moved up or down in vertical guides by the screw *s*. The motor *m* is arranged to drive the screw *s* at various speeds through a train of gears. Thus by lowering the jar *j* the electrolyte can be drained out through the bottom of the battery *b* at any desired rate.

The cells were connected to a 110-volt circuit through a series resistance in imitation of the conditions in a 110-volt battery, except in the last six tests under group C, in which a 240-volt circuit was used. Various rates of lowering the electrolyte that would empty the cells in about one minute to several hours were used, but there was no marked difference in the results.

TABLE 8.—*Summary of leakage tests on battery cells.*

Test conditions.					Test results.				
							Ignition.		
	Number of cells.	Number of tests.	Was test made with cell charging or discharging?	Was external circuit opened when electrolyte cleared bottom of plate?	Arcing between plates.	Short circuits between plates.	Number.	Number of cells in which they occured.	Average time elapsing between instant electrolyte cleared plates and ignition (minutes).
Group A	1	21	Charging	Yes					
Do	1	23	Discharging	Yes					
Do	1	2	Charging	No			2	1	12.5
Do	1	8	Discharging	No		In at least 3 cases.	[a] 5		9.4
Group B	7	4	Charging	No	None	In 4 cases [b]			
Do	7	47	Discharging	No	In 27 cases	In 21 cases	15	3	33
Group C	4	2	Charging [c]	No	In 2 cases	In 1 case			
Do	4	14	Discharging [d]	No	In some cases.	In 2 cases.			

[a] In addition, ignition occurred twice when, by mistake, a current of 60 amperes was passed through a cell that was standing with the electrolyte below the level of the plates after a discharge test in which the circuit had been opened at the time the liquid cleared the plates.

[b] These tests were made on cells that short-circuited consistently.

[c] One of these tests was made to represent a very slow leak; the cell went through two cycles of charge and discharge.

[d] One of these tests was made under both charging and discharging conditions.

RESULTS.

As shown in Table 8, 69 tests were made with discharging cells in which the circuit remained closed after the electrolyte had been drained away, and in 20 of these tests explosions occurred. The short circuits between the plates which took place in at least 26 of the tests probably prevented a larger number of explosions, for when the cells short-circuited during a test the chance of arcing and explosion seemed greatly reduced or wholly eliminated. Although an analysis was not made in this test, an analysis in the evaporation test showed the gases were nonexplosive in that test after short-circuiting had taken place.

CONCLUSIONS.

The number and scope of these tests were not great enough to cover all of the conditions that might arise in operation, or to give conclusive results, but they show that explosion is likely to occur in some types of batteries if the electrolyte is allowed to leak until it is below the plates. Under the same conditions in other types, the chance of explosion seems to be less. In these latter cells enough of the liquid appears to be vaporized by the heat generated, as a result of the increased resistance, to dilute or drive off the explosive gas before arcing could occur.

Although a test was not made, enough explosive gas might accumulate even in these cells, if the circuit was allowed to remain open after draining the electrolyte, to cause an explosion upon applying voltage to or passing current through the drained cell.

Internal short circuits in a cell prevent arcing and reduce the danger of explosion, and this fact seems to account for the nonoccurrence of explosions in the evaporation tests. However, an easily short-circuited cell would probably be undesirable for other reasons.

The tests show that every precaution to guard against low electrolyte must be taken if storage batteries are to be made safe for use in gaseous places.

LIABILITY OF DANGEROUS CURRENT LEAKAGE OVER SURFACE OF CELLS AND TRAYS.

Batteries, especially during charge, give off a spray from the electrolyte that tends to keep the cells and trays moist, and mine air is ladened with dust particles that settle over the surface of the batteries. The following tests were made to determine whether or not such accumulations of coal dust and electrolyte would permit a flow of leakage current sufficient to produce electric arcs and flashes, or a heat intense enough to ignite explosive mixtures of methane and air:

MATERIAL TESTED.

Two classes of tests were conducted.

In tests of class 1 the current leakage over various paths of rock maple wood saturated with electrolyte was tested; in those of class 2 standard locomotive battery cells and trays were used, with leakage paths similar to those in standard equipments. The two different electrolytes used to saturate the leakage paths are designated type A and type B.

CURRENT LEAKAGE OVER MAPLE WOOD SATURATED WITH ELECTROLYTE.

Preliminary tests were made to standardize a method for obtaining maximum saturation of the wood. The direction of the grain of the wood with relation to that of the leakage path was found to have no material influence on the results. The best method was to apply the electrolyte in grooves cut lengthwise of the leakage paths and in such amounts that all of it would be absorbed or evaporated before voltage was applied to the path.

For this reason the resistance measurements and "breakdown tests" of the paths were made 24 hours after the electrolyte had been applied. This test consisted in subjecting the "leakage path" to a difference of potential from a 200-volt d. c. supply, connected through a protective resistance that would limit the current to five amperes should the leakage path's resistance become too low.

RESULTS.

The results in Table 9 were obtained from the various tests, electrolyte being applied once a day to the leakage paths.

The resistances of the paths varied, depending chiefly upon the amount of electrolyte applied, the amount absorbed or evaporated, the degree of saturation of the wood, and the extent to which the wood was attacked by the electrolyte. The resistances of the paths treated with type A electrolyte were lowered much more than those of paths treated with type B electrolyte.

The results show dangerous conditions exist with wooden leakage paths as long as 20 inches when the paths are saturated with type A electrolyte and 3 inches when they are saturated with type B electrolyte. Although resistance measurements indicate that the tests with type B electrolyte had not been long enough to reach complete saturation, it is doubtful if conditions could be as dangerous with this electrolyte as with the other.

TABLE 9.—*Summary of conditions and results of surface-leakage tests on maple-wood leakage paths.*

Type of electrolyte.	Number of paths tested.	Number of days tested.	Length of leakage paths.	Conditions resulting from breakdown test.	Remarks.
A	[a] 5	14	3 inches	Dangerous in 3 cases. No breakdown test made on other two paths.	2 tests across and 2 with grain.
A	[b] 12	10	3 inches	Dangerous after some days' treatment.	1 path subjected to breakdown test each successive day.
A	[c] 6	22 to 26	14, 18, and 20 inches.	Dangerous in all tests. Breakdown tests made on only 3 paths (6 tests made in all).	First breakdown tests were made after 22 days' treatment.
B	12	10	3 inches	Not dangerous	Test method identical with test of 12 paths treated with type A electrolyte.
B	17	29	Twelve 3-inch, five 20-inch.[d]	Dangerous conditions on 3-inch paths.	Only 2 breakdown tests made; one on a 3-inch path and one on an 18-inch length of a 20-inch path.

[a] One of these paths had been used in preliminary tests.

[b] Only 10 paths were subjected to the breakdown test.

[c] Tests made over different lengths of each path.

[d] These same paths were used in the 12 tests above; this is merely a continuation of those tests.

CURRENT LEAKAGE OVER THE SURFACE OF VARIOUS TYPES OF BATTERY CELLS AND TRAYS.

The length of leakage paths in battery equipments were found by calculation to be shorter sometimes than those used in the tests with maple-wood leakage paths.

However, the paths of the battery equipments differ, being composite and made up of rubber, metal, wood, etc. Furthermore, there is the possibility of dirt accumulating over the surface of the cell tops and trays. For these reasons paths representing the minimum leakage paths obtainable with standard battery cells and trays were prepared. Coal dust and electrolyte were applied daily during the tests and a difference of potential maintained across the paths continuously during working hours, except during the time allowed for application of electrolyte and coal dust. Applications of electrolyte and coal dust were made in most of the tests three times daily, and usually at least 40 minutes was allowed between time of application and time of applying voltage, but during both the tests at 200 volts and during part of the one at 100 volts with the alkaline battery, applications were made only once a day.

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The condition of the two leakage paths at the end of the last two tests is shown in Plate II, *B* at *a* and *b* (p. 13). The two bottles in the foreground were used to spray the electrolyte on the paths.

A condensed summary of the results of the tests is given in Table 10.

TABLE 10.—*Summary of conditions and results of surface-leakage tests with minimum-leakage paths of various storage batteries.*

Type of electrolyte used.	Voltage applied to leakage paths.	Number of days treatment before breakdown.	Conditions in leakage paths during tests.	Remarks.
B	200	40	Sparking noted at various times before breakdown.	Flames burst from path upon application of power after 40 days' test.
B	100	14	Coal dust dully incandescent for a short time on fifth and ninth days.	Few sparks noted before breakdown but boiling electrolyte and charring frequent. Severe sparkings at breakdown.
B	75	63	Dense smoke given off on several occasions. No sparks noted.	Test had been run for 2 months previously and then postponed. At breakdown, flames 3 or 4 inches high burst from path.
B	60	92	Puffs of smoke noted after twentieth day. Burning of the cell insulation noted after eighty-third day.	Test run 87 days without breakdown. After 71 days' interval tests were resumed, path became red hot, and broke down in 5 days; arcs and flame were noted. Path was ½ inch high with coal dust after 87 days.
B	30	No breakdown.	Unsafe conditions after twentieth day.	Test discontinued after 92 days. Path cleaned after 38 days and thereafter applications made more sparingly.
A	200	25	Sparks and dangerous conditions noted several times.	Conditions obviously dangerous toward the end of test and therefore test discontinued.
A	100	96	Slight sparking on fifth day, and dangerous sparking on twentieth, thirtieth and thirty-ninth days.	Test was run without breakdown for 87 days. Then, after having postponed for 71 days, path broke down in 9 days.
A	75	No breakdown.	Smoking and sparking throughout test. Dangerous arcing in the last 2 days.	Test discontinued after 87 days. After 34 days the coal dust had reached a depth of over ½ inch. Path cleaned and thereafter applications made more sparingly.

CONCLUSIONS.

This test shows that an accumulation of dirt and electrolyte on the cell tops is dangerous and uneconomical. The leakage of current causes both loss of power and rapid deterioration of the cells from heat and electrolytic action. These conditions can be avoided only by proper inspection and care of the battery.

APPLICATION OF INFORMATION FROM OTHER INVESTIGATIONS.

Work previously done in connection with the approval of coal-cutting equipment under Bureau of Mines Schedule 2–A was of great value in outlining the tests for the accessories of storage battery locomotives. Motor, controller, rheostat, and fuse compartments of various kinds and arrangements and employing different methods of protection had already been tested under that schedule. The data obtained had determined the general nature of the conditions that would be met in testing similar equipment for battery locomotives, and made preliminary investigations of this apparatus unnecessary.

Tests on coal-cutting equipment showed the necessity of isolating interconnecting compartments to prevent the so-called "heaping effect"—that is, the propagation of a pressure wave ahead of the flame of a gas explosion, which results in an enormous pressure at the end of a long passage. The tests showed the high efficiency of flange protection for isolated compartments, and also showed that the internal pressure resulting from an explosion of gas and air in such a flange-protected compartment usually will not exceed 80 to 100 pounds per square inch.

FIELD INVESTIGATIONS.

Considerable information was obtained through the laboratory tests, conferences with the manufacturers, and from the suggestions and criticisms of engineers; it was supplemented by field data concerning the actual dangerous conditions and troubles that were resulting from the introduction of battery-locomotive haulage in mines. The bureau submitted to a number of operators a questionnaire dealing with matters relating to the behavior of storage batteries in mine locomotives, and the bureau's engineers made personal inspections to obtain first-hand information on actual conditions to which the locomotives were subjected in service.

INFORMATION FROM QUESTIONNAIRES.

Replies to the questionnaires were received from about 53 mine operators covering about 240 locomotives of various makes, equipped with various types of batteries.

About 17 per cent of the reports showed that repairs to battery plates had been necessary; 11 per cent that internal explosions, due to low electrolyte or short circuits of battery plates, had occurred in battery cells; 64 per cent showed cracked or leaky battery jars; 45 per cent showed trouble from broken leads or connectors; and 15 per cent showed arcing due to current leakage over the battery cells or trays. It should be remembered that the locomotives reported had not been specifically designed for use in gaseous mines, and that since the older locomotives were first installed, improvements have been made both in locomotive and battery design. Some of the locomotives had been in service more than seven years, although probably not with the original batteries.

The remarks appended to the answers of the returned questionnaires showed that some of the troubles were the result of improper

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care or use of the batteries and that some of the causes of trouble could be removed by changes in design. One report told of arcing that was injurious enough to damage materially a battery cell, this damage resulting from a small detached nut that had gone astray in the battery compartment. To guard against danger from the same or similar causes, the battery compartment, with its necessary ventilating openings, must be constructed so as to prevent the accidental or intentional introduction of any conducting material into it when closed, and all metallic parts within the compartment must be so designed and guarded that they shall not cause grounds or short circuits.

Although the data gained from the questionnaires were not as exact or as comprehensive as had been anticipated, much valuable and interesting general information relating to the performance of the batteries was obtained. The batteries seem to have given fairly satisfactory service, and even in the less satisfactory equipments some of the troubles were due to remediable defects in design or to improper use and care of the batteries. Adequate inspection and intelligent handling of any machine is necessary to maintain its efficiency and safety, because no apparatus can be made absolutely fool-proof or self-maintaining. Proper attention is particularly necessary for the battery of a storage-battery locomotive.

PERSONAL INSPECTION BY BUREAU ENGINEERS.

Personal inspection by bureau engineers of locomotives revealed that although the locomotives had not been specifically designed or guaranteed by the manufacturers as safe for use in gaseous mines, they were being used in such places by operators under the impression that they were entirely safe. The machines were providing satisfactory haulage in most mines, and especially good results were obtained where they were given intelligent and conscientious care.

Experience has shown that the increased efficiency, freedom from operating troubles, and longer life of the batteries through proper maintenance more than repay the extra labor and expense involved. Lack of adequate charging equipment and inattention to the state of the electrolyte probably had much to do with the poor work of some of the batteries. The batteries of certain of the locomotives were being charged without the use of measuring instruments, and the value of charging current and amount of charge were a matter of guess.

As regards safety, none of the locomotives inspected could be considered permissible for use in gaseous mines. Cell tops in some batteries had been blown off as the result of short circuits caused by the iron battery-box covers coming in contact with the cell terminals. Proper insulation, construction, and the use of locked compartments, as required by Schedule 15, would have prevented such explosions. Broken battery jars and cell tops were common, and in one or two instances trouble had been experienced from loose or broken connectors. Failure to keep the cells and trays free from dirt and electrolyte had sometimes caused dangerous conditions, besides damaging the battery and lowering its efficiency. The contrast in the results obtained between well and poorly maintained equipments showed conclusively that the explosion hazard from storage batteries is greatly increased through inefficient handling.

The headlights, resistors, controllers, switches, and general wiring of the machines inspected presented much more dangerous conditions than the batteries. Many front glasses of headlights were broken and on many locomotives the whole lighting unit was damaged. Usually this was due to flimsy construction of the headlights and to the exposed positions in which they were mounted, which, in view of the liability of gas ignition from smashed headlight bulbs and from electric sparks, constitutes a grave source of danger in a gaseous mine.

Some machines had resistors installed in exposed places without adequate mechanical protection and with no provision against gas ignition. The light sheet-metal covers over the resistance units of several of these locomotives had been burned through by arcs, due to the grounding of the covers on the resistors in consequence of their use as convenient seats by men riding on the locomotives.

Many of the controllers were of the open type and produced dangerous flashes in operation. Some machines had controllers that were reasonably safe. Two features in the design of some of the controllers lessen the safety and the efficient operation of the locomotives. One is the absence of separate reverse levers. The other is a method of connection whereby, under certain conditions, power is drawn from only part of the battery, making one section of the battery liable to have to do more than its share of work. This might easily result in injury to the cells from overload and overdischarge, and also from overcharge unless special means were provided for separately charging the different sections of the battery.

On many of the machines the wiring was installed without adequate mechanical protection, and sometimes the live parts of switches, fuses, etc., were exposed to accidental contact. Moreover, in general no means were provided to guard against gas ignition by flashes produced in the operation of such auxiliary apparatus, and on most of the machines the battery change-over switches were not locked so as to prevent their operation in gaseous places.

SECOND CONFERENCE JULY 29, 1919.

The preparation of a schedule for storage-battery mine locomotives, which had been temporarily dropped during the war period, was resumed early in 1919. Prior to the war a specification generally acceptable had been prepared by the bureau with the cooperation of the various manufacturers. That specification, as stated in the preface of this report, was a second draft of the original specifications drawn by the bureau as a result of the conference of May, 1916, and was developed from the first draft through the criticisms of those interested and the information gained by the bureau in its various laboratory and field investigations.

In reply to inquiries by the bureau, on resuming the work, as to the continued cooperation of the various manufacturers, a new conference was suggested because of the lapse of nearly three years. Accordingly such a conference was held at the Bureau of Mines Building, Pittsburgh, Pa., on July 29, 1919. Nine representatives from five locomotive manufacturing companies and four from storage-battery companies conferred with the bureau's representatives and discussed the bureau's proposed schedule of requirements for permissible storage-battery locomotives for use in gaseous mines, and several changes, which were acceptable to the bureau, were suggested.

After the conference the bureau revised its schedule, as far as possible, along the lines suggested and published it as Schedule 15, which is reprinted below.

PROSPECTIVE TESTS UNDER SCHEDULE 15.

At least eight companies who now manufacture storage-battery locomotives for mine service have manifested an interest in the permissibility of such locomotives. If each manufacturer should submit but a single equipment under the schedule, the total work involved would make this a major investigation in the bureau's safety-first program.

It is hoped that the preliminary investigation reported herein will be of assistance to those manufacturers who are developing equipment to meet the requirements of the schedule.

At the time of writing this paper (May, 1920) several applications for test of storage-battery locomotives had been received, and the bureau looks forward to no small task in its efforts to establish a new line of permissible equipment which should render mine haulage in gaseous mines much safer.

PROCEDURE FOR ESTABLISHING A LIST OF PERMISSIBLE STORAGE-BATTERY LOCOMOTIVES FOR USE IN GASEOUS MINES: CHARACTER OF TESTS AND CONDITIONS UNDER WHICH TESTS AND INSPECTIONS WILL BE MADE.

PRELIMINARY STATEMENT.

AUTHORIZATION.

An act of Congress (37 Stat., 681) approved February 25, 1913, contains the following provision in regard to tests or investigations performed by the Bureau of Mines:

> That for tests or investigations authorized by the Secretary of the Interior under the provisions of this act, other than those performed for the Government of the United States or State governments within the United States, a reasonable fee covering the necessary expenses shall be charged according to a schedule prepared by the Director of the Bureau of Mines and approved by the Secretary of the Interior, who shall prescribe rules and regulations under which such tests or investigations may be made. All moneys received from such sources shall be paid into the Treasury to the credit of miscellaneous receipts.

The Bureau of Mines is prepared at its Pittsburgh experiment station to conduct tests of those parts of storage-battery locomotives that might cause an ignition of gas, for the purpose of determining the permissibility of such parts and approving as permissible for use in gaseous mines the locomotive that contains them.

DEFINITIONS.

Adequate. The word "adequate" means appropriate and sufficient as determined by mutual agreement of the manufacturers and the United States Bureau of Mines.

Approved. "Approved" means accepted as suitable by the bureau.

Normal operation. "Normal operation" means the performance by each part of the equipment of those functions for which each part was designed.

Permissible. "Permissible" means approved by the bureau as permissible for use in gaseous mines.

CONDITIONS UNDER WHICH TESTS AND INSPECTION WILL BE MADE.

The conditions under which the Bureau of Mines will inspect and test motors, controllers, rheostats, batteries, and other electrical accessories of storage-battery locomotives to establish their permissibility for use in gaseous mines are as follows:

1. The tests will be made at the experiment station of the Bureau of Mines, at Pittsburgh, Pa.

2. Applications for tests shall be addressed to the Director, Bureau of Mines, Washington, D. C., and shall be accompanied by a complete description of the equipment to be tested and a full set of the drawings mentioned below:

A drawing or drawings clearly showing the character, size, and relative arrangement of the complete locomotive. The drawing or drawings shall specify the material of which all parts are made.

A drawing or drawings showing in detail all parts of such locomotives as might cause an ignition of gas.

Any other drawings necessary to identify or explain any feature that is to be considered in the approval of the locomotive or its accessories.

A copy of the description, a duplicate set of the drawings, shall be sent to the electrical engineer, Bureau of Mines, 4800 Forbes Street, Pittsburgh, Pa.

3. As soon as possible after receipt of his application for test the manufacturer will be notified as to the date on which his equipment will be tested and the amount of accessory parts that it will be necessary for him to submit.

4. The manufacturer shall deliver to the Bureau of Mines, 4800 Forbes Street, Pittsburgh, Pa., two weeks prior to the date set for the test, the necessary parts for determining the permissibility of his locomotive. The manufacturer shall provide a man to assist in the conduct of the tests and shall make preliminary preparations for conducting the tests, such as drilling and tapping the various accessory parts to accommodate the necessary pipe connections. The manufacturer, if he so desires, may have a representative present throughout all the tests.

5. No one is to be present during the permissiblity tests except the necessary Government officers at the experiment station, their assistants, representatives of the manufacturer of the locomotive under test, and such other persons as may be mutually agreed upon by the manufacturer and the bureau.

6. Permissibility tests of accessories for storage-battery locomotives will not be made unless such accessories have been completely developed and are in a form which can be put on the market.

7. Tests will be made in the order of the receipt of application for them, provided that the necessary equipment is submitted at the proper time.

8. The details of the results of the tests shall be regarded as confidential by all present at the tests and shall not be made public in any way prior to the formal approval of the locomotive by the Bureau of Mines.

REQUIREMENTS FOR APPROVAL OF STORAGE BATTERY LOCOMOTIVES.

CLASSIFICATION OF PARTS.

The various parts of a storage-battery locomotive equipment that may cause an ignition of gas shall be divided into four classes:

Class 1.—Class 1 shall include all parts—such as motors, controllers, resistance, fuses, and switches—that while in service in gaseous places may produce sparks or flashes as the result of normal operation.

Class 2.—Class 2 shall include all parts that may produce sparks or flashes as the result of normal operation, but need not be operated while the locomotive is in a gaseous place. These include the change-over switch for battery, or interlocking fuses that can not be inserted or removed when the circuit is alive and can not cause an explosion of gas.

Class 3.—Class 3 shall include all parts that do not produce sparks or flashes as the result of normal operation, but may do so as the result of an accident. Such parts include the battery cells, battery wiring, headlight, instruments, and wiring.

Class 4.—Class 4 shall include all mechanically held connections not inclosed in permissible compartments.

GENERAL REQUIREMENTS PRESCRIBED FOR EACH CLASS.

Class 1.—All class 1 parts shall be inclosed in permissible compartments.

Class 2.—All class 2 parts shall be completely inclosed in compartments of adequate mechanical strength that are either permissible compartments or locked with an adequate lock.

Class 3.—All class 3 parts shall be provided with adequate mechanical protection of a strength and character proportionate to the risk of injury or with permissible inclosures.

Class 4.—All class 4 parts shall be designed with an adequate factor of safety to insure reliability.

DETAILED REQUIREMENTS.

BATTERIES.

Battery inclosures shall be made of wood reinforced with steel, or of steel with a cover lined with insulation of adequate quality and dimensions.

Unless the battery cells are insulated from the trays in an approved manner the battery trays shall be insulated from the battery box with porcelain or equivalent insulators of adequate dimensions.

Connections between cells and between trays and connections to the outgoing circuit shall conform to the requirements for class 4 parts.

Circuits shall leave the battery inclosures through metal conduit.

If the charging contacts are alive while the battery is discharging, and if the receptacle that contains the charging contacts is on the outside of the battery inclosure, this receptacle shall conform to the requirements for class 2 parts.

AUTOMATIC CIRCUIT-INTERRUPTING DEVICES.

Automatic circuit-interrupting devices shall be inclosed in permissible compartments and shall be designed so that the device may be reset or renewed quickly and conveniently without meanwhile causing any of the permissible features of the locomotive to be less effective.

HEADLIGHT.

The headlight shall be inclosed so as to insure adequate protection of the bulb from mechanical injury. The headlight circuit shall be provided with a switch and fuses.

MAIN SWITCH AND FUSES.

Between the battery and the controller there shall be a double-pole main switch and fuses adequate for the control of the amount of power involved. These shall be installed together or separately in permissible compartments.

CONDUCTORS AND WIRING.

All wiring not inclosed in locked or permissible compartments shall be in metal conduit.

SPECIAL REQUIREMENTS FOR CLASS 1 PARTS.

CONSTRUCTION.

The construction of class 1 parts must be especially durable. This requirement will be applied consistently to all the details of the parts under test in order that with proper care and maintenance the permissible qualities of the part will remain unimpaired under the severe conditions imposed by mining service.

Any protective devices used with such parts must not only be capable of preventing the passage of flames from the interior to the exterior of the casing, but must also possess sufficient mechanical strength to insure against the accidental destruction of their protective qualities. If there are moving parts in connection with such devices, these parts should be so designed that there can be no interference with their movement.

All leads entering permissible compartments should pass through the casing in the form of properly protected insulated studs of approved design. The use of rubber bushings will not be approved because the bushings may become displaced and thus destroy the permissibility of the casing.

All joints in the casings of a permissible compartment must be metal-to-metal joints with faces not less than 1 inch wide. All bolt holes in casings must be bottomed or so arranged that the accidental omission of a bolt will not give an opening through the casing. All openings in the casings of permissible compartments other than those provided with protective devices by the manufacturers must be tightly closed. It is desirable that such openings be as few as possible.

CHARACTER OF TESTS.

In testing class 1 parts to establish their permissibility the casings will be filled and surrounded with the most explosive mixture of Pittsburgh natural gas and air. The mixture within the casings will be ignited by a spark plug or other suitable means.

Similar tests may also be made with greater and with less amounts of gas in the explosive mixture and with coal dust sifted into the casing or into the protective devices. Tests will be made to determine the point of ignition that gives the greatest pressure. Not less than 10 tests will be made for each permissible compartment and more than that number if, in the opinion of the bureau's engineers, more tests are necessary to prove the permissibility of the compartment under test.

As a result of the permissibility tests of any compartment or compartments the internal explosion within the compartment or compartments shall not ignite the gas surrounding the equipment nor discharge flames from any of the compartments. Neither shall there be developed dangerous afterburning[a] or excessive pressure in any of the compartments.

SPECIAL REQUIREMENTS FOR COMPLETE LOCOMOTIVES.

Locomotives will not be considered as permissible if used under any of the following conditions:

If used without the approval plate mentioned hereafter.

If used with openings in any of the permissible compartments other than those openings provided with protective devices by the manufacturer. This condition refers to all openings but especially to those closed by removable covers during normal operation.

If the locomotive when in operation is not complete with all of the parts considered in its approval.

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[a] The term "afterburning" as used in this schedule is applied to the combustion, immediately after an explosion within a permissible compartment, of a gaseous mixture that was not within the casing at the time of the explosion, but was drawn in subsequently while the products of the explosion were cooling.

The manufacturer shall be required to attach to the locomotive frame an approval plate bearing seal of the Department of the Interior, Bureau of Mines, and an appropriate caution statement.

The size, material and design of the approval plate shall be subject to the approval of the bureau. The manufacturer will be furnished a photographic print of the wording and seal to be incorporated in the approval plate design.

NOTIFICATION OF MANUFACTURER.

As soon as the bureau's engineers are satisfied that a locomotive is permissible for use in gaseous mines the manufacturer shall be notified to that effect.

As soon as the manufacturer receives formal notification that his locomotive has passed the tests prescribed by the bureau he shall be free to advertise such locomotive as permissible.

DRAWINGS OF APPROVED LOCOMOTIVES TO BE FILED.

As the safety of a permissible locomotive depends largely on its construction, the approval of a locomotive must identify the details of construction on which the approval is based. This identification will be accomplished by reference to a list of drawings and photographs that show in detail such parts as directly or indirectly affect the safety of the locomotive or any of its accessories. Each list of drawings will be given a number to facilitate reference. A copy of each drawing will be filed with the Bureau of Mines.

SCOPE OF APPROVAL.

The bureau's approval of any locomotive shall be construed as applying only to locomotives of the specific type, class, form, and rating that have the same construction in the details directly or indirectly affecting the safety of the locomotive as the one inspected, tested, and approved for permissibility by the bureau.

However, the bureau recognizes that under the conditions peculiar to mining there is a demand for diversified types. Therefore, the original approval will be made to cover as many forms or modifications of a given type of locomotive as the manufacturer may request, provided that he submits drawings which clearly show the nature and extent of such changes, and provided that such forms or modifications are consistent with the principles of safety.

Manufacturers shall, before claiming the bureau's approval for any further modification of an approved locomotive, submit to the bureau drawings that shall show the extent and nature of such modifications in order that the bureau may decide whether test of the remodeled part will be necessary for approval.

WITHDRAWAL OF APPROVAL.

The bureau reserves the right to rescind for cause, at any time, any approval granted under the conditions herein set forth.

FEES FOR TESTING STORAGE-BATTERY LOCOMOTIVES.

The following fees, to be charged on and after the date of approval of this schedule, have been established and approved by the Secretary of the Interior:

ITEM 1. COMPLETE TESTS.

For a complete official investigation of a storage-battery locomotive, including inspections and 75 tests to determine its permissibility for use in gaseous mines, $250.

ITEM 2. EXTRA TESTS.

It is estimated that 75 tests should be sufficient to determine the permissibility of the average equipment submitted, but the design may be such as to require more than this number of tests to determine the point at issue. Such extra tests will be charged for in amounts proportionate to the work involved.

ITEM 3. SPECIAL TESTS.

Special tests to assist the manufacturer in the development of equipment will be made at his request and will be charged for in accordance with the work involved. Each request for special tests should be accompanied by a fee of $100, made payable to the Secretary of the Interior. Any unused moneys from such deposits will be refunded at the completion of the special tests on request by the manufacturer.

ITEM 4. SEGREGATED CHARGES.

The following charges will be made for tests made separately or repeated during the course of an investigation:

Complete preliminary inspection		$25.00
Tests to prove the permissibility of parts under class 1:		
Motor	$37.50	
Controller	37.50	
Resistance	37.50	
Fuses and switches	37.50	
		150.00
Tests and inspections necessary to prove the adequacy of parts under classes 2, 3, and 4		50.00
Complete final inspection		25.00
Total		250.00

SYNOPSIS OF PROCEDURE TO BE FOLLOWED IN MAKING APPLICATION FOR TESTS, SUBMITTING MATERIAL, CONDUCTING TESTS, AND NOTIFYING APPLICANT OF RESULTS.

1. Application for tests should be addressed to the Director of the Bureau of Mines, Washington, D. C. This application should be accompanied by check or draft made payable to the Secretary of the Interior, and by a complete rating of the parts to be tested, and a set of the drawings described under the foregoing heading, "Drawings of approved locomotives to be filed." Duplicate copies of the application and drawings should be sent to the electrical engineer, Bureau of Mines, 4800 Forbes Street, Pittsburgh, Pa.

2. As soon as the application has been reviewed by the bureau's engineers the applicant will be notified of the date of tests.

3. After the applicant has received this notification, he should send the material required to the electrical engineer, Bureau of Mines, 4800 Forbes Street, Pittsburgh, Pa. The material should be delivered not less than two weeks in advance of the date set for the beginning of the tests.

4. The tests will be begun on the date set and continued until the locomotive has been approved, rejected, or withdrawn.

5. After the bureau's engineers have considered the results of the tests, a formal report of the approval or disapproval of the locomotive will be made to the applicant in writing by the Director of the Bureau of Mines. No verbal report will be made, and the details of the tests must be regarded as confidential by all present.

The rules and regulations, including fees, set forth in this schedule shall be immediately effective upon the approval of the schedule and shall take the place of previous regulations published on pages 9 and 10 of Schedule 2A in so far as it applies to test of storage-battery locomotives.

VAN. H. MANNING,
Director.

Approved August 16, 1919.
S. G. HOPKINS,
Assistant Secretary.

PUBLICATIONS ON INVESTIGATIONS OF ELECTRICAL EQUIPMENT.

A limited supply of the following publications of the Bureau of Mines has been printed and is available for free distribution until the edition is exhausted. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list showing all its publications available for free distribution as well as those obtainable only from the Superintendent of Documents, Government Printing Office, on payment of the price of printing. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

BULLETIN 46. An investigation of explosion-proof mine motors, by H. H. Clark. 1912. 44 pp., 6 pls., 14 figs.

BULLETIN 52. Ignition of mine gases by the filaments of incandescent electric lamps, by H. H. Clark and L. C. Ilsley. 1913. 31 pp., 6 pls., 2 figs.

BULLETIN 68. Electric switches for use in gaseous mines, by H. H. Clark and R. W. Crocker. 1913. 40 pp., 6 pls.

BULLETIN 78. Approved coal-cutting equipment, by L. C. Ilsley and E. J. Gleim. 1920. 53 pp., 18 pls., 3 figs.

BULLETIN 131. Approved electric lamps for miners, by H. H. Clark and L. C. Ilsley. 1917. 59 pp., 17 pls., 7 figs.

TECHNICAL PAPER 19. The factor of safety in mine electric installations, by H. H. Clark. 1912. 14 pp.

TECHNICAL PAPER 22. Electrical symbols for mine maps, by H. H. Clark. 1912. 11 pp., 8 figs.

TECHNICAL PAPER 44. Safety electric switches for mines, by H. H. Clark. 1913. 8 pp.

TECHNICAL PAPER 47. Portable electric mine lamps, by H. H. Clark. 1913. 8 pp.

TECHNICAL PAPER 58. Action of acid mine water on the insulation of electrical conductors, a preliminary report, by H. H. Clark and L. C. Ilsley. 1913. 26 pp., 1 fig.

TECHNICAL PAPER 75. Permissible electric lamps for miners, by H. H. Clark. 1914. 21 pp., 3 figs.

TECHNICAL PAPER 79. Electric lights for oil and gas wells, by H. H. Clark. 1914. 8 pp.

TECHNICAL PAPER 108. Shot firing in coal mines by electricity controlled from the outside, by H. H. Clark, N. V. Breth, and C. M. Means. 1915. 36 pp.

TECHNICAL PAPER 138. Suggested safety rules for installing and using electrical equipment in bituminous-coal mines, by H. H. Clark and C. M. Means. 1917. 36 pp.

MINERS' CIRCULAR 5. Electrical accidents in mines, their causes and prevention, by H. H. Clark, W. D. Roberts, L. C. Ilsley, and H. F. Randolph. 1911. 10 pp., 3 pls.

PUBLICATIONS THAT MAY BE OBTAINED ONLY THROUGH THE SUPERINTENDENT OF DOCUMENTS.

TECHNICAL PAPER 4. The electrical section of the Bureau of Mines, its purpose and equipment, by H. H. Clark. 1911. 12 pp. 5 cents.

TECHNICAL PAPER 23. Ignition of mine gas by miniature electric lamps with tungsten filaments, by H. H. Clark. 1912. 5 pp. 5 cents.

TECHNICAL PAPER 28. Ignition of mine gas by standard incandescent lamps, by H. H. Clark. 1912. 6 pp. 5 cents.

TECHNICAL PAPER 101. Permissible explosion-proof electric motors for mines; conditions and requirements for test and approval, by H. H. Clark. 1915. 14 pp., 2 pls., 1 fig. 5 cents.

TECHNICAL PAPER 159. Production of explosives in the United States during the calendar year 1915, with notes on coal-mine accidents due to explosives and a list of permissible explosives, lamps, and motors tested prior to June 1, 1916, compiled by A. H. Fay. 1916. 24 pp.

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